International Journal of Sustainability, Disaster and Environmental Management (IJSDEM), Vol. 1, No. 1, 2025. Available online at https://transglobalpunet.com/index.php/ijsdem. Indexed in google scholar, etc.
Jacob Eriti Abel, Akwaowo D. Denny & Victor Eyo (2025), IJSDEM,1(1):46-61

Effect of Kerosene on the Respiratory Organ (Gill) of African Catfish (*Clarias gariepinus*)

Jacob Eriti Abel[1], Akwaowo D. Denny[2], Victor Eyo[3]

[1&3]Department of Fisheries and Aquaculture, Faculty of Oceanography, University of Calabar, Calabar, Nigeria.

[2]Department of Environmental Management, Faculty of Environmental Science, University of Calabar, Calabar, Nigeria.

[1]**Corresponding author's Email** address: eritijacob1998@gmail.com

Abstract

This study investigated the effect of kerosene on the respiratory organ (gill) of juvenile African catfish (Clarias gariepinus) under laboratory condition for 96hours. A total of hundred and twenty (120) juvenile C. gariepinus was used in six (6) different aquaria having duplicates i.e. ten (10) juveniles each were grouped into twelve (12) different test aquaria and held for 24, 48, 72 and 96 hours in six (6) different concentrations of kerosene (0, 0.4,0.8, 1.2, 1.6, 2.0ml/L). At the end of the test period, histopathological examination of the gills was conducted. The LC50 of kerosene in the water was noted to be 1.05ml/L. During the period of exposure of test fish to this toxicant, respiratory distress, aggression, weakness, erratic swimming, loss of balance, sluggish movement were common reactions of the test fish at the time of toxicant application before death. It was also observed that mortality was toxicant dependent (i.e. the higher the concentration of toxicant the higher the number of dead fish recorded). Histopathological examination of the gills exposed to kerosene showed lesions, degradation of filament, and necrosis with increasing concentration of kerosene, which in relation to previous studies indicates reduced dissolved oxygen level, resulting in respiratory challenge/difficulty. All the juveniles held in the control aquaria showed no histopathological degradation. Conclusively, this study has been able to reveal that exposing juvenile African catfish to even low concentrations of kerosene could lead to histopathological damage on the fish gill structure. Conclusively, a safe concentration was established using an application factor of 0.01 (for industrial chemicals and pesticides). We arrived at safe concentration level of 0.0105 ml/L. Thus, if the kerosene concentrations remain below 0.0105 ml/L, juveniles of C. gariepinus as well as other aquatic species will suffer no adverse effects.

Keywords*: Kerosene; Clarias gariepinus; Respiratory organ; histopathological effect; Nigeria.*

1.0 Introduction

Kerosene is a refined petroleum product comprising hydrocarbon mixtures with carbon chains ranging from 11 to 18 atoms per molecule (Ekejiuba, 2021). Its versatility makes it widely used as fuel for automobiles, generators, heating, cooking, and aviation, as well as in industrial applications such as paint and grease production (Kakodia et al, 2024). However, the increasing reliance on petroleum products has led to growing environmental concerns, particularly regarding their effects on aquatic ecosystems (Ukhurebor et al., 2021; Adeola et al., 2022). Oil spills, pipeline corrosion, vandalization, and accidental discharges are among the primary causes of oil pollution, introducing hydrocarbons like kerosene into freshwater and marine environments (Edori et al., 2014). Crude oil and its refined products, including kerosene, pose significant threats to aquatic ecosystems (Shah and Soni, 2024). They reduce dissolved oxygen availability, disrupt biochemical and physiological

activities of aquatic organisms, and accumulate in food chains, resulting in long-term ecological damage (Kakodia et al, 2024). These pollutants often impact fish, which serve as bioindicators due to their sensitivity to changes in water quality (Ivon et al., 2021). Behavioral, haematological, and histopathological alterations in fish exposed to pollutants are frequently used as biomarkers to assess contamination levels (Eseigbe et al., 2013). Despite the wealth of studies on crude oil toxicity, limited research has focused specifically on kerosene's toxic effects on fish health and physiology (Adeola et al., 2022). Earlier studies have demonstrated that water-soluble fractions of crude oil impair fish growth, induce physiological stress, and affect survival (Santos et al., 2022). These findings underscore the need for further investigation into the specific concentration thresholds at which petroleum fractions become toxic to aquatic organisms (Chukwu & Okhumale, 2009).

In Nigeria's Niger Delta region, petroleum exploration has contributed significantly to national wealth but has also resulted in widespread environmental degradation (Bamidele and Erameh, 2023). Oil spills, operational discharges, and sabotage of petroleum infrastructure have led to pollution of aquatic ecosystems, threatening biodiversity and regional fisheries (Nwilo et al., 2006). The release of hydrocarbons such as kerosene into water bodies often occurs through runoff, erosion, and accidental discharges during transportation and storage, exacerbating contamination levels (Kanungo et al., 2024 Scheren et al., 2002; Adam et al., 2002). Additionally, environmental contamination by petroleum products is particularly concerning because of its persistence and long-term impacts. While hydrocarbons in kerosene undergo photodegradation in air and biodegradation in soil and water, the initial exposure can cause irreversible harm to aquatic life (Pauline, 2006). Fish, being intimately connected to their aquatic environment, are particularly vulnerable to such pollution. For instance, petroleum products disrupt oxygen exchange at the gills, impair metabolic processes, and accumulate in tissues, leading to physiological stress and mortality (Nwamba et al., 2006). The ecological and socio-economic implications of kerosene pollution are far-reaching (Bashir, 2021). Fish mortality and population decline disrupt fisheries, which are critical for food security and livelihoods in developing countries (Daniel-Kalio et al., 2002). Additionally, contamination of aquatic ecosystems reduces water quality, impacting other organisms and human populations that depend on these resources. Given the importance of fish such as C. gariepinus in aquaculture and the broader ecosystem, understanding the toxicological effects of kerosene is imperative. Several studies have been conducted on the exposure of C. gariepinus to various pollutants. Abdel-Moneim et al. (2008) conducted a study on the physiological and histopathological effects of juvenile catfish exposed to dyestuff and chemical waste water. Doherty et al. (2013) conducted another study on the toxicological effect and histopathology of C. gariepinus exposed to water soluble fractions of Diesel and kerosene. George et al. (2014) investigated the acute toxic effect of Qua Iboe light crude oil on the gills of C. gariepinus juveniles. Esie (2018) also conducted a study on the effects of produced water on juvenile C. gariepinus. Additionally, Edori et al. (2014) conducted a study on the comparative toxicity of petrol and kerosene to periwinkle (Tympanotonus fuscatus). Moreover, Gabriel et al. (2007), conducted a study on the haematology and gill pathology of C. gariepinus exposed to refined petroleum oil, kerosene under laboratory conditions, amongst other studies. However, these studies have never investigated the effect of kerosene fraction of crude oil on the respiratory organ (gills) of C. gariepinus a key species in Nigerian aquaculture industry. Therefore, the main aim this study was to determine the effects of kerosene on the respiratory organ (gills) of juvenile C. Gariepinus by specifically looking at a) To determine the LC50 of kerosene on the C. Gariepinus b) to determine the safe concentration of kerosene on C. gariepinus c) to determine the histopathological effect of kerosene on C. gariepinus and d) to check behavioural changes in the C. gariepinus.

2.0 Materials and methods

2.1 Study area

This study was conducted at the University of Calabar, Faculty of Oceanography in the Laboratory of Fisheries and Aquaculture Laboratory (Figure 1).

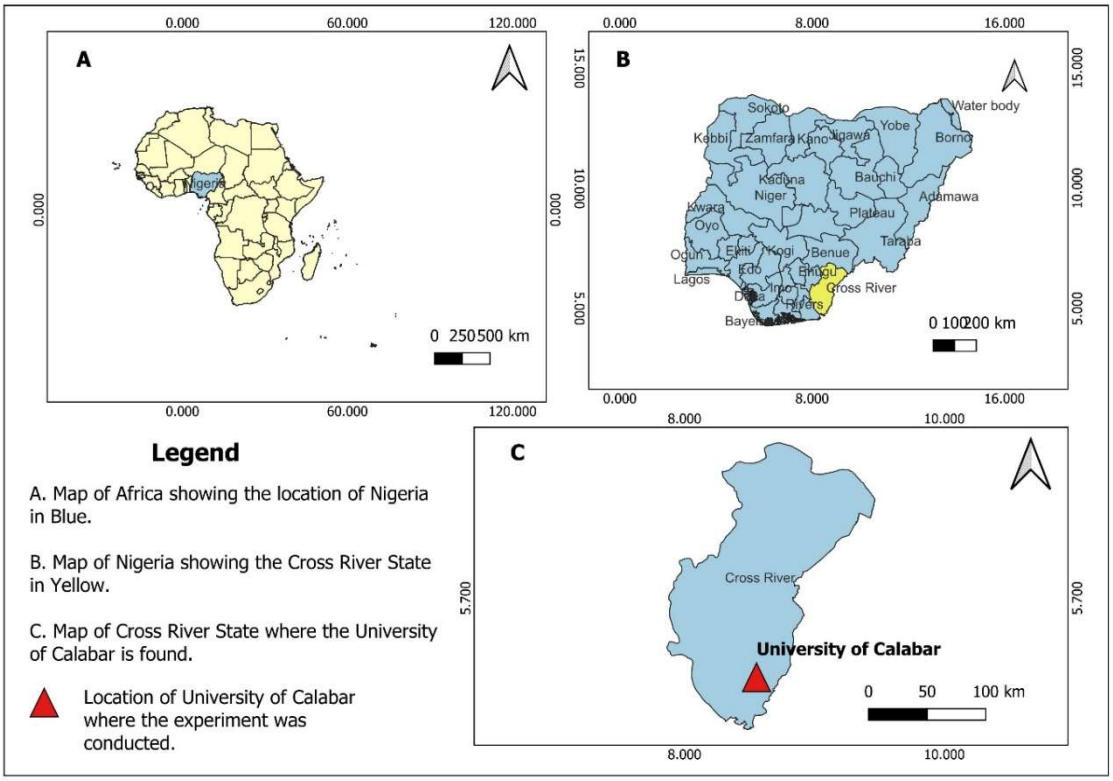

Fig 1: Map showing the location of University of Calabar where the experiment was done.

2.2 Specimen collection and acclimatization

A total of 100 healthy juveniles of C. *gariepinus* of mean weight (1.31 ± 0.56 g) and mean total length (5.62 ±0.61 cm) were purchased from University of Calabar fish farm and hatchery complex located at Latitude 04O5″02′N and Longitude 008020″ 450'E respectively (Akpan et al., 2002). The fish was transported to Fisheries and Aquaculture Laboratory, Faculty of Oceanography, University of Calabar with the aid of 20 Liters plastic container. The fish was kept in 20 Liters plastic tanks and acclimatized to laboratory conditions for a period of two weeks prior to the start of the experiment. During acclimatization, the fish was fed with 2 mm Coppen fish feed containing 45% crude protein (Table 1) at 5 % of their body weight twice daily, between the hours of 8:00-9:00hr and 17:00-18:00 pm. Water quality was managed by changing of water in the aquaria daily between the hours of 6am-7am.

Table 1: Composition of Coppens feed

Composition	Percentage (%)
Crude protein	45
Ash	9.55
Crude fibre	12

Crude fat	1.5
Phosphorous	2

Source: Manufacturer

2.2 Experimental design

2.2.1 Collection of Kerosene

Five (5) litres of kerosene used for this experimental study was purchased from the Fynefield Plc, located at Goldie Road, Calabar, Cross River State.

2.2.2 Range finding test

After the period of acclimatization, a preliminary range finding test was conducted following standard methods of APHA (2005) to determine the concentrations that was used in the actual experiment. Ten (10) fish each was placed in five different exposure chambers having five (5) litres of water each with replicate having a broad range of concentrations (0, 1, 2, 3, and 4 ml/l). Survival and mortality were recorded after 1 and 24 hours and the results were used to determine the definitive test concentrations.

2.2.3 Acute Toxicity Test

After the range finding test, six concentrations of kerosene were used to conduct acute toxicity test under standard bioassay procedure. Mortality was monitored for 96 hours. Any fish that fails to move its body was classified "dead". Floating or sunk fish which do not move was brought out and classified dead using a pair of gloves and recorded.

2.2.4 96 Hours Lethal Concentration (LC50)

The 96-hour LC50 was estimated using the methods recommended by UNEP (1989).

2.2.5 Measurement of water quality parameters

pH, temperature and dissolved oxygen was monitored during the test period according to standard method of the American Public Health Association (APHA, 1989). pH level was measured using pH meter (pH Model SAEG pHS-25C. Temperature was measured using thermometer (mercury in glass thermometer). Dissolved oxygen level was measured using DO meter (MW600 Dissolved oxygen Milwaukee Smart DO meter).

2.3 Physicochemical analysis of kerosene

The physicochemical analysis of the kerosene used in this study was done using standard American water was carried out using standard American Public Health Association (APHA) methods

2.3.1 Odour and colour

The odour and colour of kerosene used in this study was determined using physical observation with the nose and eye respectively.

2.4 Monitoring of specimen for death rate

Any animal (fish) that fails to move its body was classified "dead. Floating or sunk fish which do not move was brought out and classified dead using a pair of gloves and recorded.

2.5 Histopathology of the gills

The gills were extracted from the test fish at each concentration and processed manually following the stepwise procedure described by Bancroft and Cook (1994). Initially, the gills were fixed in 10% formalin for 48 hours and thoroughly washed with water to remove excess fixatives. The fixed tissues were dehydrated in ascending grades of ethanol (30%, 50%, 70%, 90%, and 100%) for at least two hours in each solution. Dehydrated tissues were cleared in xylene to enhance microscopic examination, starting with a 1:1 mixture of chloroform and xylene, followed by pure xylene. The tissues were then impregnated with paraffin wax, melted at 60°C, and left to infiltrate for two hours to facilitate sectioning with a microtome. The gills were embedded in molds, blocked out on wooden blocks for microtomy, and sectioned using a rotary microtome at 10 µm thickness. The sections were stained using hematoxylin and eosin methods, and photomicrographs of the stained tissues mounted on glass slides were captured digitally using an Amcap microscope camera (Model DCE-2).

3.0 Results

3.1 Behavioural response of C. gariepinus exposed to kerosene

The behavioural responses observed during this study include:

a) Loss of balance

b) Erratic swimming

c) Aggression

d) Weakness

e) Death.

3.1 Mean mortality of C. gariepinus exposed to kerosene

A regular trend of mortality was observed with an increase in toxicant concentration (Table 2). At the early stage, (i.e. the first 24hrs) the mortality rate was so high, with progressive exposure of fish to toxicant, 48hrs, 72hrs and 96hrs mortality rate reduced drastically and fish started moving again freely. Between 72 and 96hrs, there were no survivors recorded in the highest concentration (2.0ml/L).

Table 2: Mean mortality of C. gariepinus exposed to kerosene

Concentration	24 hours	48 hours	72 hours	96 hours	Mortality
0.0 ml/l	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
0.4 ml/l	0.50 ± 0.50	0.00±0.00	0.00±0.00	0.00±0.00	0.50±0.50
0.8 ml/l	0.50±0.50	0.50±0.50	0.00±0.00	0.00±0.00	1.00±1.00
1.2 ml/l	6.50±2.50	0.00±0.00	0.00±0.00	0.50±0.50	7.00±2.00
1.6 ml/l	7.50±0.50	0.00±0.00	0.00±0.00	0.00±0.00	7.50±0.50
2.0 ml/l	10.0 ± 0.0	0.00±0.00	0.00±0.00	0.00±0.00	10.00±0.00

3.3 Mean percentage mortality of C. gariepinus exposed to kerosene

Results obtained for mean percentage mortality of C. gariepinus exposed to kerosene (Table 3) shows that mean mortality and mean percentage mortality was 0.00 ± 0.00 and 0.00 ± 0.00 % in 0.0 ml/L. In 0.4 ml/L, mean mortality and mean percentage mortality was 0.50 ± 0.00 and 5.00 ± 0.00%. In 0.8ml/L mean mortality and mean percentage mortality was 1.00±1.00 and 10.00±10.00%. In

1.2ml/L mean mortality and mean percentage mortality was 7.00±2.00 and 70.00±20.00%. In 1.6ml/L mean mortality and mean percentage mortality was 7.50±0.50 and 7.500±5.00%. In 2.0ml/L mean mortality and mean percentage mortality was 10.00±0.00 and 100.00±0.00%.

Table 3: Mean percentage mortality of C. gariepinus exposed to kerosene

Concentration	Mortality	Percentage mortality (%)
0.0 ml/l	0.00±0.00	0.00±0.00
0.4 ml/l	0.50±0.50	5.00±5.00
0.8 ml/l	1.00±1.00	10.00±10.00
1.2 ml/l	7.00±2.00	70.00±20.00
1.6 ml/l	7.50±0.50	75.00±5.00
2.0 ml/l	10.00±0.00	100.00±0.00

3.4 96 Hours Lethal concentration (LC50) of C. gariepinus exposed to kerosene

Results obtained for the 96 hours lethal concentration (LC50) of kerosene to C. gariepinus (Fig. 1) shows that the LC50was 1.05 ml/L.

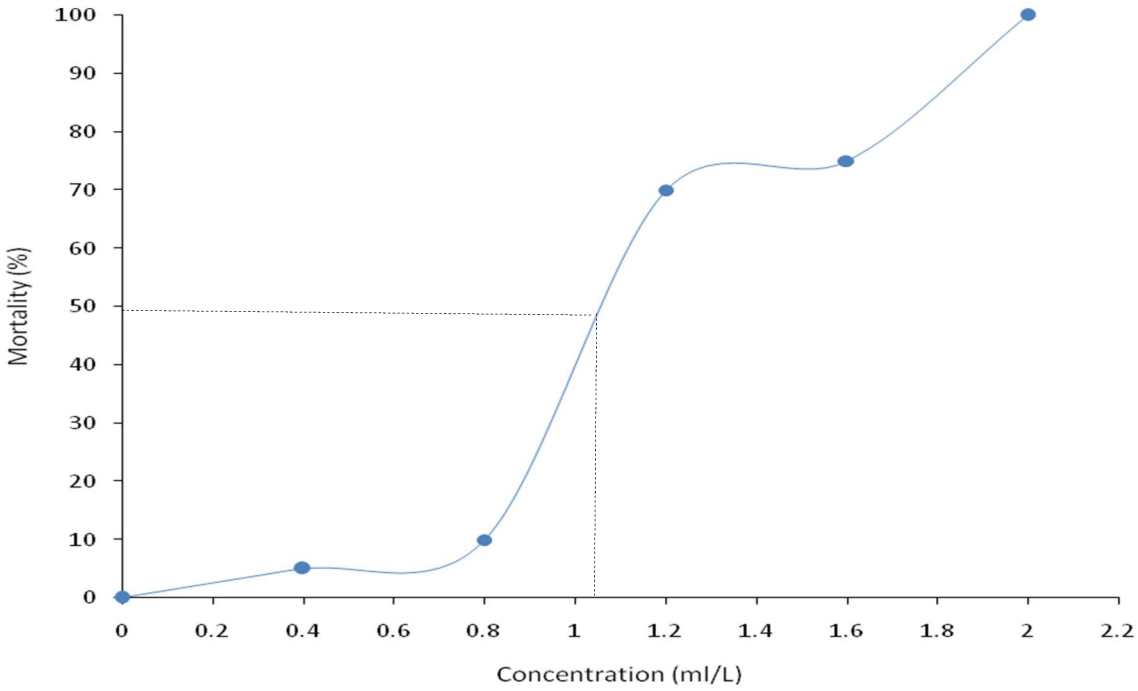

Figure 2: Mortality (%) of C. gariepinus against concentrations of kerosene showing LC50

3.5 Mean values of physico-chemical parameters measured during 96 hour exposure of kerosene to Clarias gariepinus

Results obtained for the mean physico-chemical parameters of the experimental aquaria (Table 4) shows that in 0.0 ml/L, pH was 5.82 ± 0.00, dissolved oxygen (3.60 ± 0.00 mg/L) and temperature (28.00 ± 0.00 ˚C). In 0.4 ml/L, pH was 6.20±0.00, dissolved oxygen (3.20±0.00mg/L) and temperature (28.00±0.000C). In 0.8ml/L pH was (7.19±0.00), dissolved oxygen was

(3.10±0.00mg/L) and temperature (28.00 ± 0.00 ˚C). In 1.2ml/L pH was (6.47±0.00), dissolved was (3.30±0.00mg/L), and temperature (28.00±0.000C). In 1.6ml/L pH was (6.09±0.00), dissolved oxygen was (3.30±0.00mg/L) and temperature (28.00±0.000C). In 2.0ml/L pH was (6.10±0.00), dissolved was (3.10±0.00mg/L) and (28.00±0.000C).

Table 4: Mean values of physico-chemical parameters measured during 96-hour exposure of kerosene to C. gariepinus

Concentration	pH	Dissolved oxygen (mg/l)	Temperature (˚C)
0.0 ml/L	5.82±0.00	3.60±0.00	28.00±0.00
0.4 ml/L	6.20±0.00	3.20±0.00	28.00±0.00
0.8 ml/L	7.19±0.00	3.10±0.00	28.00±0.00
1.2 ml/L	6.47±0.00	3.30±0.00	28.00±0.00
1.6 ml/L	6.09±0.00	3.40±0.00	28.00±0.00
2.0 ml/L	6.10±0.00	3.10±0.00	28.00±0.00

3.6 Histopathology of the gills of C. gariepinus exposed to different concentration of kerosene

Histopathology of the gills of C. gariepinus (Figure 3-6) exposed to different concentration of kerosene showed that in the control (0.0 ml/L), a normal gill membrane with no lesion, necrosis and inflammation was obtained. In 0.8ml/L, gills showed slight necrosis and degeneration filament. In 1.6ml/L gills showed degeneration of filament and in 2.0ml/L gills showed severe degeneration of filament, necrosis and areas of lesion.

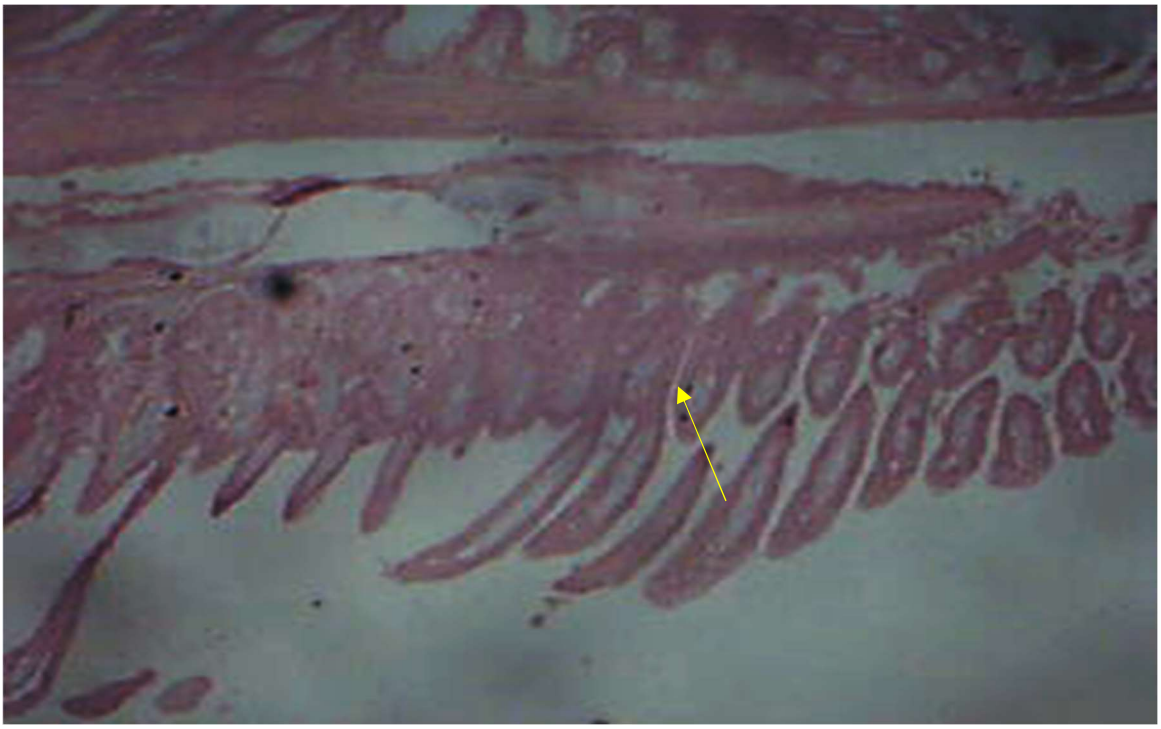

Figure 3: Control (Arrow shows normal gill membrane with no lesion, necrosis and inflammation)

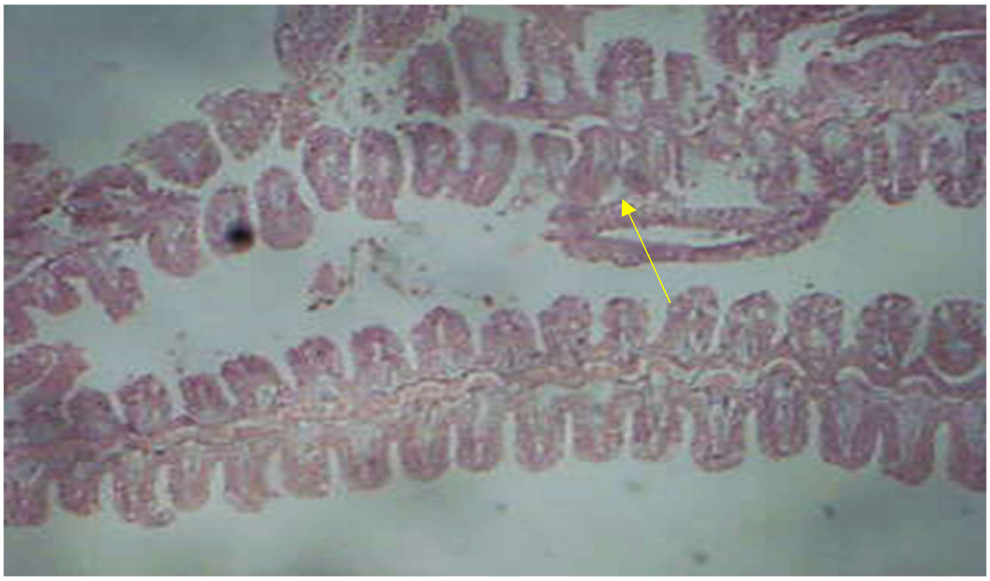

Figure 4 : 0.8 ml/L (Arrow shows slight necrosis and degeneration of filaments)

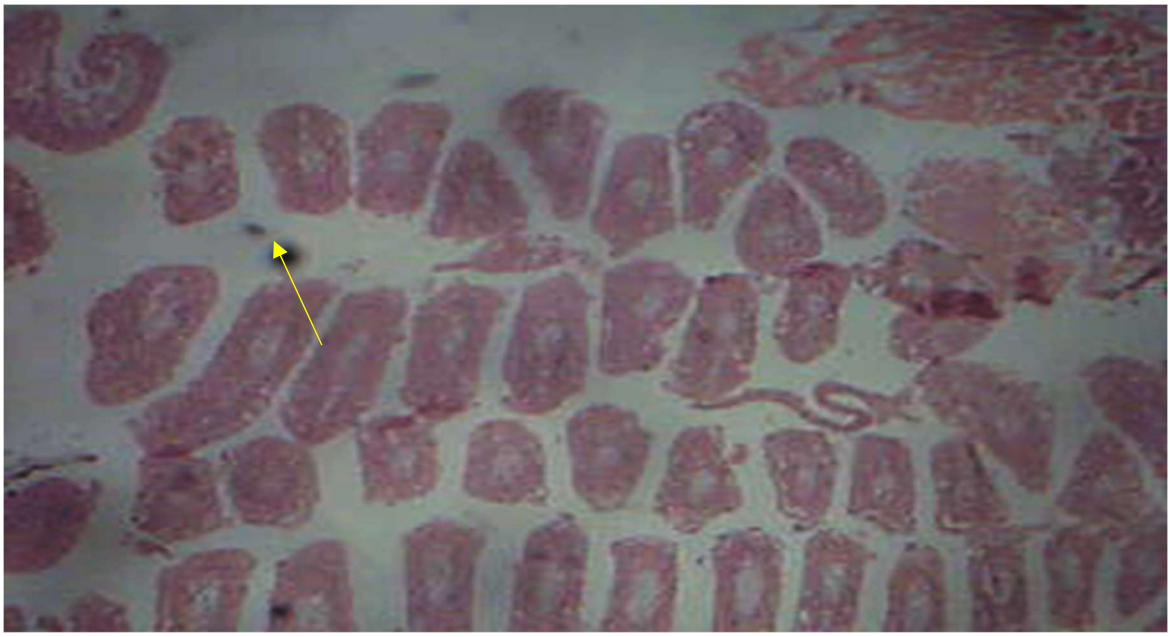

Figure 5: 1.6 ml/L (Arrow shows degeneration of filaments)

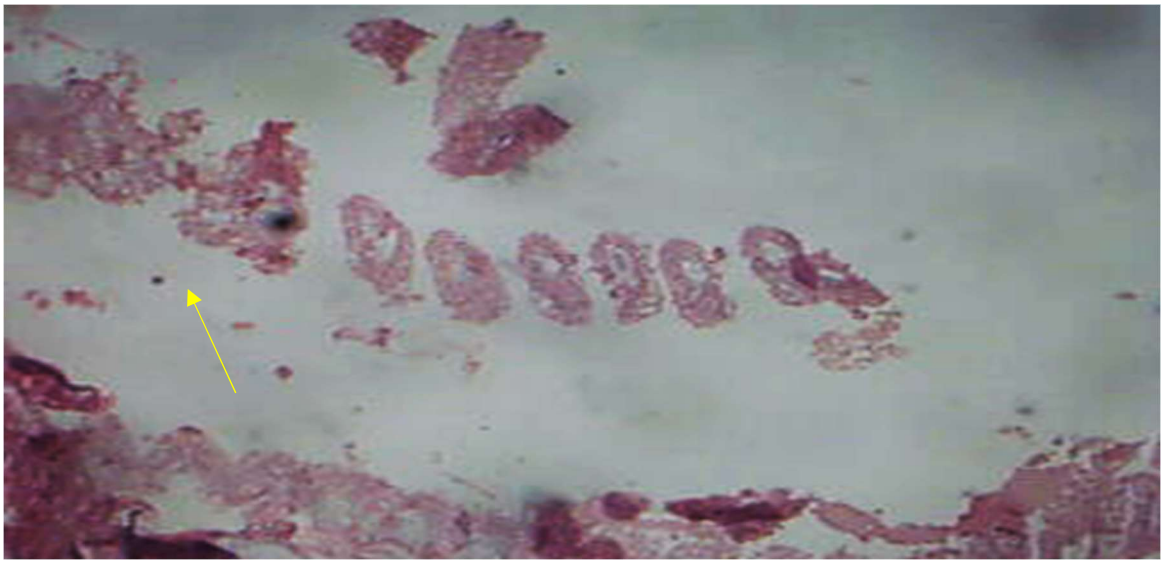

Figure 6: 2.0 ml/L (Arrow shows severe degeneration of filaments, necrosis and areas of lesion)

4.0 Discussion

The constant exposure of fish to toxic substances leads to high mortality rate in the aquatic ecosystem. Dead fishes were carefully identified by absolute lack of movement and were removed as soon as they were detected. There were no survivors recorded in the highest concentration (2.0ml/L), no mortality was observed in the control tank. Three basic physico-chemical parameters of water were measured before stocking of the fish and within the 96 hours introduction of the toxicant. Dissolved oxygen had a value range of 3.1–3.6, with a temperature of 280C and a pH range of5.82–7.19. In fisheries and aquaculture, all these parameters have standard values or acceptable range of values. For dissolved oxygen, a range of 6.0mg/L, for pH a range of 6.7–8.6 and for temperature a range of 250C–300C (Ajah, 2007; Smith, 1982; Udo, 2007). The ranges of the physico-chemical parameters of the experimental water were found to fall into the acceptable range before the commencement of the experiment as previously reported by the authors under reference.

In the present study, percentage mortalities were concentration-dependent. The higher the concentration, the higher the percentage mortalities. Similar report was presented by Ogundiran et al. (2010) while investigating the toxicological impacts of detergent effluent in fingerlings of African catfish *Clarias gariepinus* and George et al. (2014) while also investigating the acute toxic effect of Qua Ibo Light Crude oil on the gills of *Clarias gariepinus* juveniles. Calta et al. (2004) when studying the acute toxicity of the synthetic pyrethrioid deltamethrin to young mirrow carp, Cyprinus carpio, Ayotunde et al. (2011) while investigating the toxicity of Carica papaya on adult C. *gariepinus*, Ayuba and Ofojekwu (2002) while investigating on acute toxicity of diazinion to African catfish *Clarias gariepinus*.

In this study, the 96 hours LC50 of 1.05ml/L obtained from the experimental design is in close range with the LC50OF 1.08ml/L obtained during a study on acute toxicity of water-soluble fractions (WSF) of kerosene on Nile tilapia, Oreochromis *niloticus* fingerlings under laboratory condition, undergone by Absalom et al. (2009). The effect of the kerosene observed histopathologically showed a severe destruction of the gill lamellae of *Clarias gariepinus*. However, the gill lamellae of the fish in the control medium (0ml/L) showed no effect on the gill, i.e. the gill lamellae were normal with

no lesion, necrosis and inflammation. In the 0.8ml/L concentration of toxicant it was observed that the gill lamellae of the fish eroded and showed slight necrosis and degeneration filament. In 1.6ml/L concentration of toxicant the gill lamellae of C. gariepinus were observed to have shown a degeneration of filament and a destruction of the gill secondary lamellae while in the 2ml/L concentration, it was observed that the gill showed severe degeneration of filaments, necrosis and inflammation; hyperplasic effects was observed on the gill membrane and a loss of gill membrane. These observations correlate with the concentrations of toxicants in each experimental design (aquaria), i.e., the higher the concentration of toxicant, the greater the damages done on the fish gill. These results align with what George et al. (2014) got during their study on the acute toxic effect of Qua Iboe light crude oil on gills of *Clarias gariepinus* juveniles. And also, what Absalom et al. (2009) observed during his studies on the "Acute Toxicity of Water-Soluble Fractions (WSF) of kerosene on Nile Tilapia, Oreochromis niloticus fingerlings under Laboratory Conditions." Hypertrophic, necrotic, atrophy and dystrophy of secondary lamellae have also been reported in haematology and histopathology of *Clarias garpienus* juveniles exposed to refined petroleum oil and kerosene under laboratory conditions (Gabriel et al. 2007).

The changes observed on the gills of C. gariepnus falls under the general reactions of fish species organs to toxicant and environmental pollutant, and aquatic pollution. Fernandes and Mazon (2003) observed that fish gills are the prime target organ of all pollutants due to their extensive surface in contact with the external medium and the reduced distance between the external medium, and gill morphology are important biomarkers providing a fast method of detection of the effect of pollutants (Gabriel et al., 2007; George et al., 2014).

The general morphological changes in the gills recorded in this study have been reported by Gabriel et al. (2007) in his study on haematology and gill pathology of *Clarias gariepnus* exposed to petroleum oil and kerosene as a current study by George et al. (2014) on the acute toxic effect of Qua Iboe Light Crude oil on the gills of C. gariepnus still reveals same. Fish mortality could also have resulted from direct toxicant of the kerosene. The behavioural observations reported in this experiment have been reported by several other toxicants. Ayuba and Ofojekwu (2002), Svecevicius (2006), George et al. (2014), Absalom et al. (2009), Edori et al. (2014) and Gabriel et al. (2007). Respiratory struggle noticed in exposed fish could be as a result of mucous precipitation on the gill epithelia in response to the toxicant which result in abnormal behaviour as stated by Banerjee (2007).

In fish, direct contact between the aquatic environment and the gill epithelium may cause these surfaces to become sensitive to environmental alteration in the presence of toxic substances and irritants (Absalom et al., 2009). A regular trend of increased mortality was observed with increase I toxicant concentrations showing a dose-response relationship100% mortality was recorded in the group with the highest concentration of toxicant, i.e. 2.0ml/L, 75% to 1.6ml/L, 70% to 1.2, 10% to 0.8ml/L, 5% to 0.4ml/L and 0% to control group. The mean value of 96-hour LC50 of kerosene to the test fish was calculated to give 1.05ml/L (different LC50 values have been recorded for different contaminants/toxicants, variation in LC50 may also be as a result of differences in type, size, age and strength of the exposed fish and technical grade involved in toxicant preparation) (Palanivela et al., 2005). The dead fish in all the toxicant exposures showed fishes with brownish gills and this corresponds with the findings of Absalom et al. (2009). The plate 1 above shows the distribution of gills in a normal fish control (0ml/L) of kerosene; plate 2 shows the kerosene action on the fish at 0.8ml/L concentration; and plate 3 shows the action of the toxicant to the fish at 1.6ml/L, plate 4 shows the reaction of kerosene (toxicant on the fish gills at 2ml/L which was the highest concentration.

5.0 Conclusion and recommendations

The results of this study demonstrate that kerosene, even at low concentrations, is highly toxic to C. gariepinus. Short-term exposure to concentrations exceeding 1.6 ml/L induces significant stress responses in fish, including behavioral changes such as loss of balance, erratic swimming, aggression, weakness, and ultimately high mortality, particularly at higher concentrations due to kerosene-induced stress on the fish's immune system. Histological analysis of the gills revealed vascular congestion, hyperplasia, and loss of the gill membrane, highlighting the toxic effects of kerosene on vital fish organs. As such, there is an urgent need for caution to prevent kerosene contamination in aquatic environments caused by oil refinery activities, pipeline vandalism, accidents, or improper waste disposal. The findings emphasize that kerosene levels in aquatic ecosystems should not exceed 1.05 ml/L, based on the 96-hour LC50 value identified in this experiment. Overall, preventing kerosene contamination is vital for preserving aquatic biodiversity and ensuring the sustainability of aquaculture sector and we recommend that oil companies must adopt ecologically friendly practices for managing spills and waste and adherence to standard waste disposal methods and prompt action during accidental spills.

Acknowledgements

Conflicts of Interest
The authors have no conflicts of interest to declare.

Authors' Contribution
Conceptualization: JEA; Supervision: APE & VE; Resources mobilization: JEA; Data Collection and Investigation: JEA; Materials and Methodology: JEA; Writing the Original Draft Manuscript: JEA, APE & VE; Data Curation, Software, and Formal Analysis: JEA; Visualization and Project Administration: JEA; Validation and Review Editing: JEA, APE & VE. All author reviewed the final manuscript and approved its submission to the journal for publication.

Data availability statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

6.0 References

Abdel-Moneim, A. M., Abou, S. M. & Abdel-Kader, H. H. (2008). Physiological and histopathological effects in catfish (Clarias lazera) exposed to dyestuff and chemical wastewater. International Journal of Zoological Research, 4, 189-202.

Absalom, K. V., Ajima, M. N. O., Nwani, C. D. & Ayodele, B. J. (2009). Acute toxicity of water-soluble fractions (WSF) of kerosene on Nile tilapia, Oreochromis niloticus fingerlings under laboratory condition. Journal of Exp. Zoology India, 12(2), 297-300.

Adeola, A.O., Akingboye, A.S., Ore, O.T., Oluwajana, O.A., Adewole, A.H., Olawade, D.B. and Ogunyele, A.C. (2022). Crude oil exploration in Africa: socio-economic implications, environmental impacts, and mitigation strategies. Environment Systems and Decisions, 42(1), pp.26-50. https://doi.org/10.1007/s10669-021-09827-x

Adomotai, R. & Sheate, W. R. (2004). Community participation and environmental decision-making in the Niger Delta. Environmental Impact Assessments Review, 24(5), 495-518.

Aghalino, S. O. & Eyinia, B. (2009). Oil exploitation and marine pollution: Evidence from the Niger Delta, Nigeria. Journal of Human Ecology, 28(3), 177-182.

Ajah, P. O. (2007). Fish feeding and hatchery management. Calabar: Jerry Commercial Productions.

Akpan, E. R., Offem, I. O. & Nya, A. E. (2002). Baseline ecological studies of the Great Kwa River, Nigeria. Physico-chemical Studies African Journal of Environmental. Pollution and Health 1, 83-90.

Alonso-Alvarez, C., Pereza, C & Valendo, A. (2007). Effects of acute exposure to heavy fuel oil from the prestige spills on a seabird. Aquatic Toxicology, 84, 103-110.

Amadi, A. S. D & Nna, A. (1996). Chronic effects of oil spill on soil properties and microflora of a rainforest ecosystem in Nigeria. Water, Air and Soil Pollution, 86(1-4), 1-11.

Anoop, K. R., Sundar, K. S. G., Khran, B. A & Lal, S. (2009). Common Moorhen Gallinuta chloropus in the diet of the African catfish Clarias gariepinus in Keoladeo Ghana National Park, India. Indian Birds, 5(2), 22-23.

Anthonio, O. R. & Akinwumi, J. A. (2002). Supply and distribution of fish in Nigeria. Geographical Journal, 14, 16.

APHA (2005). Standard methods for the examination of water and waste water. 22nd Edition. Washington, DC: American Public Health Association.

Ayotunde, E. O., Ofem, B. O. & Bekah, A. F. (2011). Toxicity of Carica papaya Linn: Haematological and piscidal effect on adult catfish (Clarias gariepinus). Journal of Fisheries and Aquatic of Science, 6(3), 291-308.

Ayuba, J. O. & Ofojekwu, P. C. (2002). Acute toxicity of the root of Jonson's weed Datura innoxia to the African catfish Clarias gariepinus fingerlings. Journal of Aquatic Science, 17, 131-133.

Bamidele, S. and Erameh, N.I. (2023). Environmental degradation and sustainable peace dialogue in the Niger delta region of Nigeria. Resources Policy, 80, p.103274. https://doi.org/10.1016/j.resourpol.2022.103274

Bancroft, J. D., Cook, H. C., Stirling, R. W. & Turner, D. R. (1994). Manual of histopathological techniques and their diagnostic applications. London: Churchill Livingstone.

Banerjee, T. K. (2007). Estimation of respiratory organs of certain air-breathing fishes of India. Journal of Fish Physiology and Biochemistry, 33, 441-454.

Bashir, M.T. (2021). Environmental, public health and socio-economic issues of oil spillage in Niger Delta, Nigeria. International Journal of Engineering Research & Technology, 10(2), pp.62-66. http://www.ijert.org/

Ben-David, M., Williams, T. M. & Ormseth, O. A. (2000). Effects of oiling on exercise physiology and driving behavior of river otters: A captive study. Canadian Journal of Zoology, 78, 1380-1390.

Benka-Coker, M. O. & Ekundayo, J. A (1995). Effects of an oil spill on soil physico-chemical properties of a spill site in the Niger Delta area of Nigeria. Environmental Monitoring and Assessment, 36(2), 93-104.

Benka-Coker, M. O. & Olumagin, A. (1996). Effects of waste drilling fluid on bacterial isolates from a mangrove swamp oil field location in the Niger Delta of Nigeria. Bioresource Technology, 55(3), 175-179.

Calta, M. & Ural, M. S. (2004). Acute toxicity of the synthetic pyrethroid deltamethrin to young mirror carp, Cyprinus carpio. Freshnius Environmental Bulletin,13, 11.

Chukwu, L. O. & Okhumale, B. O. (2009). Mode of joint action response to binary mixtures of three refined petroleum products by Nile tilapia, Oreochromis niloticus fingerlings. Scientific Research and Essay, 4(8), 806-811.

Dange, A. D. & Masurekar, B. V. (1981). Toluene toxicity: Effects of sublethal levels on enzyme activities on seawater adapted tilapia (Sarotherodon mossambicus Peters). Journal of Bioscience, 3(2), 129-134.

Daniel-Kalio, L. A. & Amabaraye, S. B. (2002). The impact of accidental oil spill on cultural and natural vegetation in a wetland area of Niger Delta, Nigeria. Ambio. 31(5), 441-442.

Dede, E. B., Igboh, N. M. & Ayalogu, O. A. (2002). Chronic toxicity study of the effects of crude petroleum (Bonny light), kerosene and gasoline on rats using Haematological parameters. Journal of Applied Science, Environment and Management, 6, 60-63.

Doherty, V. F., Kanife, U. C. & Okeleye, B. T. (2013). Toxicological effects and histopathology of African catfish (Clarias gariepinus) exposed to water soluble fractions of diesel and kerosene. Current Advances in Environmental Sciences, 1(2), 16-21.

Doust, H. (1990). Petroleum geology of the Niger Delta geological society, London. Special Publications, 50(1), 365.

Eaton, J. P. (1997). The Nigeria tragedy: Environmental regulation of transnational corporations, and the human rights to a healthy environment. Boston University International Law Journal, 15, 261-571.

Edoho, F. M. (2008). Oil Transnational Corporations: Corporate social responsibility and environmental sustainability. Environmental Management, 15(4), 210-222.

Edori, O. S., Edori, E. S. & Nna, P. J. (2014). Comparative toxicity of petrol and kerosene to periwinkle (Tympanotonus fuscatus). Global Journal of Pure and Applied Sciences, 20, 25-29.

Ekejiuba, A.I. (2021). Natural Petroleum: Chemistry and Valuable Products Fractions. Carbon, 82(87.1), pp.80-85.

Emokaro, C. O., Ekunwe, P. A. & Chille, A. (2010). Profitability and viability of catfish farming in Kogi State, Nigeria. Journal of Agricultural and Biological Science, 6(3), 215-219.

Eseigbe, J., Doherty, V. F., Sogbamu, T. & Otitoloju, A. A (2013). Histopathology alterations and lipid peroxidation as biomarkers of hydrocarbon induced stress in the earthworm. Environmental Monitoring and Assessment (Springer), 185(3), 2189-2196.

Esie, N. G. (2018). Studies on the effect of produced water on juvenile African catfish (Clarias gariepinus). Unpublished Master's thesis submitted to the Department of Biotechnology, School of Biological Sciences, Federal University of Technology, Owerri, Imo State, Nigeria.

Eweje, G. (2006). Environmental costs and responsibilities resulting from oil exploitation in developing countries: The case of the Niger Delta of Nigeria. Journal of Business Ethics. 69(1), 27-56.

Food and Agriculture Organization. (2000). Fishstat Plus: Universal software for fishery statistical time series FAO Fisheries Department. Fishery Information Data and Statistics Unit.

Froese, R. & Pauly, D. (2014). Clarias gariepinus. Fishbase.

Gabriel, U. U., Ezeri, C. N. & Amakiri, E. U. (2007). Haematology and gill pathology of Clarias gariepinus exposed to refined petroleum oil and kerosene under laboratory conditions. Journal of Animal Veterinary Advances, 6, 461-465.

Genova, A. W. (2007). Oil and nationalism in Nigeria, 1970-1980. Annals of Arbor, 11.

George U. U., Urom, Sunday, E. & Etanketuk, N. (2014). Acute toxic effect of qua Ibo light crude oil on the gills of Clarias gariepinus juveniles. International Journal of Environmental .and Pollution Research, 2(2), 16-30.

George, G. U., Urom, Sunday, E. & Etanketuk, N. (2014). Acute toxic effect of Qua Iboe light Crude oil on the gills of Clarias gariepinus juveniles. International Journal of Environment and Pollution Research, 2(2), 16-30.

George, G., Etim, I. N. Ekanim, M. P. & Akpan, M. K. (2015). Acute toxic effects of Hevea brasiliensis on the gills of hatchery reared Oreochromis niloticus fingerlings. Journal of Academia and Industrial Research (JAIR), 3(11), 562-566.

Hack, R. C., Sundararaman, P., Diedjomahor, J. O., Xiao, H., Gant, N. J., May, D. E & Kelsch, K. (2000). Niger Delta petroleum systems, Nigeria: Petroleum systems of South Atlantic margins. American Association of Petroleum Geologist, 213-231.

Ibemenuga, K. N. (2013). Impacts of crude oil on freshwater fish fauna, its control and management measures. Animal Research International 10(3), 1799-1804.

Isaac, L. J., Abah, G., Akpan, B. & Ekaette, J. U. (2013). Haematological properties of different breeds and sexes of rabbit. Proceedings ofthe 18th Annual Conference of Animal Science Association of Nigeria, 24-27.

Ite, A. E. & Ibok, U. J. (2013). Gas flaring and venting associated with petroleum exploration and production in the Nigeria's Niger Delta. American Journal of Environmental Protection, 1(4), 70-77.

Ivon, E.A., Sanusi-Jadesola, F.O., Edu, N.E., Anyanwu, C.O., Ubi, G.M. and Odum, E.I. (2021). Measurement of Sub-Lethal Toxicity and Effect of Kerosene Pollutant on Hematological Profile of African Catfish (Clarias gariepinus). Annual Research & Review in Biology, 36(8), pp.1-17.

Jensen, B. M. (1994). Effects of oil pollution and cleaning in the thermal balance of birds. Environmental Pollution, 86, 207-215.

Kakodia, A.K., Awasthi, S. and Kant, R. (2024). Kerosene: Risk assessment. Overview, Toxicological Profile, Challenges, and Future Perspectives. In Hazardous Chemicals, pp. 219-233. Academic Press. https://doi.org/10.1016/B978-0-323-95235-4.00017-7

Kamalu, O. J. & Wokocha, C. C. (2011). Land resource inventory and ecological vulnerability: Assessment of Onne Area in Rivers State, Nigeria. Research Journal of Environmental and Earth Sciences, 3(5), 438-447.

Kampa, M. & Castanas, E. (2008). Human health effects of air pollution. Environmental Pollution, 151(2), 362-367.

Kanungo, J., Sahoo, T., Swain, L.P. and Behera, I.D. (2024). Toxicity of Persistent Hydrocarbon Pollutants, Sources and Sustainable Remediation Process. In Impact of Petroleum Waste on Environmental Pollution and its Sustainable Management Through Circular Economy (pp. 39-65). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-48220-5_2

Kharaka, V. K., Hanor, J. S., Heinrich, D. H & Karl, K. T (2007). Deep fluids in the continents: Sedimentary basin. Journal on treatise of Geochemistry, 1-48.

Lenartova, V., Holovska, K., Pedrajas, J. R., Martinezlara, E., Peinado, J & Lopezbarea, J. (1997). Antioxidant and detoxifying fish enzymes as biomarkers of river pollution. Biomarker, 2, 247-252.

Linden, O. & Jernelor, A. (1980). The mangrove swamp: An ecosystem in danger. Ambio (Sweden.) 9(2), 81-88.

Linden, O. & Jernelor, A. (1980). The mangrove swamp: An ecosystem in danger. Ambio (Sweden.) 9(2), 81-88.

Linden, O. (1978). Biological effects of oil on early development of Baltic herring Clupea membras. Marine Biology, 45, 273-283.

Luiselli, L. & Akani, G. (2003). An indirect assessment of the effects of oil pollution on the diversity and functioning of turtle communities in the Niger Delta, Nigeria. Annual Biodiversity and Conservation, 26(1), 57-65.

Miles, A. K. & Roster, N. (1999). Enhancement of polycyclic aromatic hydrocarbons in estuarine invertebrates by surface runoffs at a decommissioned military fuel depot. Marine Environmental Research, 47, 49-60.

Moles, A., Bates, S., Rice, S. D. & Korn, S. (1981). Reduced growth of Coho salmon fry exposed to two petroleum products, toluene and naphthalene, in fresh water. Trans America Fish Society, 110, 430-436.

Nwamba, H. O., Achikanu, C. E. & Onyekwelu, K. C. (2006). Effect of crude oil and its products on bilirubin of African catfish Clarias gariepinus. Animal ResearchInternational, 3(3), 351 353.

Nwilo, P. C & Badejo, T. O. (2006). Impacts and management of oil spill pollution along the Nigerian coastal areas. Administering Marine Spaces: International Issues. 119.

Obaje, N. G. (2009). Geology and mineral resources of Nigeria. London and Berlin: Springer.

Ogri, O. R. (2001). A review of the Nigerian petroleum industry and the associated environmental problems. The Environmentalist, 21(1), 11-21.

Ogundiran, M. A., Fawole, O. O., Aderoye, S. D. & Ayandiran, T. A. (2010). Toxicological impact of detergent effluent on juvenile of African catfish (Clarias gariepinus) (Buchell 1822). Agriculture and Biology Journal of North America, 1(3), 330-342.

Okunlola, D. O., Oloninisomo, A. O., Adeniola, A. O., Agboda, A. S & Omole, O. G. (2012). Haematology and serum quality of red Sokoto goats fed Baobab (Adansonia digitata). Fruit meal as supplement to guinea grass (Panicum maximum). Proceedings of the 17th Annual Conference of Animal Science Association of Nigeria, 427-433.

Olagunju, I. O. & Ezekiel, A. A. (2007). Economic viability of cat fish production in Oyo State. Journal of Human Ecology, 21(2), 121-124.

Omoregie, E. & Okunsebor, S, A. (2005). Levels of biochemical constituents of fish associated with water dispersed fractions of used automobile lubricants. Journal of Environmental Science and Health. Part A 40, 156-166.

Osuji, L. & Opiah, U. (2007). Hydrocarbon contamination of a terrestrial ecosystem: The case of Oshire-2 oil spill in Niger Delta, Nigeria. The Environmentalist, 27(3), 337-340. Winston, G. W. & Giulio, R. T. (1991). Pro-oxidant and anti-oxidant mechanisms in aquatic organisms. Aquatic Toxicology, 19, 137-161.

Osuji, L. C & Onojake, C. M. (2004). Trace heavy metals associated with crude oil: A case study of Ebocha oil-spill polluted site in Niger Delta, Nigeria. Chemistry & Biodiversity, 1(11), 1708-1715.

Palanivela, K., Vijayaraghan, K., Jegan, J. R. & Velan, M. (2005). Copper removal from aqueous solution by marine green alga ulva reticula. Electronic Journal of Biotechnology, 7(1).

Pauline, W. C. (2006). Reassessment of one exemption from the requirement of a tolerance for kerosene. United States Environmental Petroleum Agency. Washington D.C 20460.

Perez-lopez, M., Novoa-Valinas, M. C. & Nlelgar-Roil, M. J. (2002). Glutathione-S-transferase cytosolic isoforms as biomarkers of polychlorinated biphenyl. Experimental contamination in rainbow trout. Toxicology Letter, 136, 97-106.

Poindexter, P. M., Meraz, S. & Weiss, A. S. (2008). Women, men and news: Divided and disconnected in the news media landscape. Taylor & Francis Group.

Santos, R.M., Petry, A.C., Sousa, V.L., Souza, H.O., Azevedo, A., Soares, A.R. and Weber, L.I. (2022). Acute and subchronic effects of petroleum on the freshwater fish Hoplias aff. malabaricus. Brazilian Journal of Biology, 84, p.e253731. https://doi.org/10.1590/1519-6984.253731

Shah, G. and Soni, V. (2024). Comprehensive Insights into the Impact of Oil Pollution on the Environment. Regional Studies in Marine Science, 74, p.103516. https://doi.org/10.1016/j.rsma.2024.103516

Smith, L. S. (1982). Introduction to fish physiology. New Jersey: T. F. H. Publications.

Snowden, R. J & Ekweozor, I. K. E. (1987). The impact of a minor oil spillage in the estuarine Niger Delta. Marine Pollution Bulletin, 18(11), 595-599.

Soetan, K.O., Akenrinde, A. S & Ajibade, T. O. C (2013). Preliminary studies on the haematological parameters of cockerels fed raw and processed guinea corn (Sorghum bicolor). Proceedings of 38th Annual Conference of Nigeria Society for Animal Production.

Svecevicius, G. (2006). The use of fish avoidance response in identifying sub lethal toxicity of heavy metals and their mixtures. International Conference on Ecotoxicology. Trends and Perspectives, 17-20 September, 2006, Wilsa Poland.

Togum, V. A., Oseru, B. S. A., Ogundipe, J. A., Arewa, T. R., Hammed, A. A., Ajonijebu, D. & Mustapha, F. (2007). Effect of chronic lead administration on the haematological parameters of rabbits: A preliminary study. Proceedings of the 41th Conferences of the Agricultural Society of Nigeria, 341.

Udo, P. J. (2007). Techniques in fish farming (practice and management). Calabar: Wusen Publishers.

Ugochukwu, C. N. C. & Ertel, J. (2008). Negative impacts of oil exploration on biodiversity management in the Niger Delta Area of Nigeria. Impact Assessment and Project Appraisal, 26(2), 139-147.

Ugwuene, M. C. (2011). Effect of dietary palm kernel meal for maize on the haematological and serum chemistry of broiler turkey. Nigeria Journal of Animal Science. 13, 93-103.

Ukhurebor, K.E., Athar, H., Adetunji, C.O., Aigbe, U.O., Onyancha, R.B. and Abifarin, O. (2021). Environmental implications of petroleum spillages in the Niger Delta region of Nigeria: a review. Journal of Environmental Management, 293, p.112872. https://doi.org/10.1016/j.jenvman.2021.112872

Vassiliou, M. S. (2009). The A to Z of the petroleum industry. New Jersey: Scarecrow Press (Rowman and Littlefield). 700.

Westernliagen, W. (1989). Sublethal effects of pollutant on fish eggs and larvae: Fish physiology. San Diego Academic Press, 253-345.

Wilson, R. W & Taylor, E. W (1993). The physiological responses of freshwater rainbow trout, Onchonynchus mykiss, during acute exposure. Journal of Comp. Physiology, 163, 36-47.